TITLE OF THE INVENTION:

FUEL INJECTOR

BACKGROUND OF THE INVENTION:

<Field of the Invention>

The present invention relates to a fuel injector for use in an internal combustion engine.

<Prior Art>

Fuel injectors for use in an in-cylinder injection type engine include one so designed as to ensure that, as set forth in Japanese Application Patent Laid-Open Publication No. Hei 11-159421, the marginal portions of the fuel injection hole exit form an oblique plane not vertical to the body axial line of the fuel injector, that the restraint force for restraining the flow of the fuel in the radial direction of the injection hole changes in a circumferential direction, and that the spraying reach of the fuel which has been injected from injection hole marginal portions small in the restraint force is long and the spraying reach of the fuel which has been injected from injection hole marginal portions large in the restraint force is short. In this case, spraying is stabilized and the fuel is supplied in the direction of ignition plugs, with the result that the stability of stratified combustion is ensured.

In the injection of a fuel for its homogeneous combustion, it is important for the injected fuel to be sufficiently mixed with air during the period up to ignition. To achieve this, therefore, there arises the need for the distribution of flow rate to be adjustable between the fuel sprayed towards the ignition plugs of the combustion chamber after being injected, and the fuel sprayed towards the pistons.

The fuel injectors in prior art, however, are intended to improve combustion stability by making it easy for the fuel to reach the ignition plugs principally during stratified combustion, and no such fuel injectors are described that are designed so that the flow rate distribution ratio of the fuel injected and sprayed for the air intake stroke occurring during homogeneous combustion differs between fuel spraying towards the pistons and fuel spraying towards the ignition plugs.

SUMMARY OF THE INVENTION:

The object of the present invention is to supply a fuel injector by which spraying patterns different in flow rate distribution ratio can be formed to accelerate the mixing of a sprayed fuel with air and thus to improve the stability of homogeneous combustion.

A difference between the flow rate distribution ratio

of the fuel sprayed towards the pistons and that of the fuel sprayed towards the ignition plugs can be generated by providing downstream with respect to and outside the injection hole of the fuel injector a flow restraint means for restraining the flow of the fuel, and making said flow restraint means restrain the flow of the fuel in at least two places so as to split the injected fuel into portions high in spraying density and portions low in spraying density and so as to generate a difference in quantity between the split portions high in spraying density.

The flow restraint means described above can be implemented by providing in almost parallel to the above-mentioned injection hole a wall surface for restraining the flow of the fuel in its radial direction, or by providing in almost parallel to the central axis of the injection hole a plurality of wall surfaces for limiting the flow of the injected fuel. The formation of these wall surfaces enables the creation of a plurality of restraint areas in which the flow of the fuel in its radial direction or in its flow direction is to be restrained, and a plurality of release areas in which the fuel can flow in its radial direction.

In a fuel injector for use in an in-cylinder injection type internal-combustion engine, it becomes possible, by assigning a different size to the multiple release areas

mentioned above, to form spraying patterns so that during the spraying of the fuel injected from the injection hole, the density distribution of the sprayed fuel at a cross section vertical to the body axial line of the fuel injector concentrates in approximately two directions, and so that the spraying pattern of the fuel is set to ensure that the flow rate of the sprayed fuel in one of the two directions of concentration is greater than the flow rate of the fuel in the other direction.

As a result, according to the fuel injector of the present invention, spraying into a density distribution asymmetrical to the injection hole axis can be formed and when this fuel injector is used in an in-cylinder type of internal-combustion engine, the flow rate distribution ratios of the fuel sprayed towards the ignition plugs of the engine and the fuel sprayed towards the pistons can be optimized according to the particular mixing ratio of the fuel and air.

BRIEF DESCRIPTION OF THE DRAWINGS:

FIG. 1 is a cross-sectional view showing an embodiment of the fuel injector pertaining to the present invention;

FIG. 2 is an enlarged cross-sectional view of the neighborhood of the injection hole in the fuel injector pertaining to the present invention;

FIG. 3 is a front view of the neighborhood of the injection hole in the fuel injector when seen from the direction of arrow III in FIG. 2;

FIG. 4 is a further enlarged front view of the neighborhood of the injection hole shown in FIG. 3 (cross-hatching denotes the bump portion in the frontal direction of the paper surface);

FIG. 5 is an enlarged view of the neighborhood of the injection hole in another embodiment of the fuel injector having fuel flow restraint means as wall surfaces (cross-hatching denotes the bump portion in the frontal direction of the paper surface);

FIG. 6 is an enlarged view of the neighborhood of the injection hole in the fuel injector shown in FIG. 4, and showing an embodiment in which the means for restraining the flow of fuel in a radial direction is provided as an extension to the injection hole (cross-hatching denotes the bump portion in the frontal direction of the paper surface);

FIG. 7 is a cross-sectional view showing epitomically the spraying pattern obtained by using the fuel injector of the present invention;

FIG. 8 is a cross-sectional view showing an embodiment in which the fuel injector pertaining to the present invention is mounted in an internal-combustion engine;

FIG. 9 is a cross-sectional view and front view showing an embodiment of the fuel injector pertaining to the present invention;

FIG. 10 is a further enlarged view of the neighborhood of the injection hole in the fuel injector shown in FIG. 9;

FIG. 11 is an enlarged front view showing the neighborhood of the injection hole in an embodiment of a fuel injector having a function equivalent to that of the fuel injector shown in FIG. 5 (cross-hatching denotes the bump portion in the frontal direction of the paper surface); and

FIG. 12 is a cross-sectional view showing the spraying status of a fuel.

DESCRIPTION OF THE INVENTION:

FIG. 1 is a cross-sectional view showing the structure of an embodiment of the fuel injector pertaining to the present invention. The fuel injector in FIG. 1 is a normally closed type of electromagnetic fuel injector, in which a valve body 102 and seat portion 202 are in firm contact when power is not supplied to a coil 109. A fuel is supplied from a fuel supply port under the status that pressure is assigned by a fuel pump not shown in the figure, and the fuel passageway 106 of the fuel injector is filled

with fuel up to where the valve body 102 and seat portion 202 are in firm contact. When power is supplied to coil 109 and valve body 102 leaves the seat portion, the fuel will be injected from injection hole 101. In this sequence, the fuel flows to injection hole 101 through a rotational groove provided in a rotating element 107. When the fuel flows through the rotational groove in rotating element 107, rotational force is assigned to the fuel to ensure that the fuel is rotationally injected from injection hole 101.

FIG. 2 is a cross-sectional view showing in enlarged form the neighborhood of the open end of the injection hole in the fuel injector shown in FIG. 1, and FIG. 3 is a front view of the corresponding portion when seen from the direction of arrow III in FIG. 2. FIG. 2 also corresponds to a cross-sectional view of the portion when seen from the direction of arrow II-I in FIG. 3. In addition, an injection hole central axis 200 routing through the center of injection hole 101 and running in the axial direction of the fuel injector (namely, the direction along the valve axis center) is shown with a single-dashed line in FIG. 2. This direction of injection hole central axis 200 agrees with the driving direction of valve body 102. Furthermore, a line segment routing through the center of injection hole 101 and running orthogonally with respect

to injection hole central axis 200, and a line segment routing through the center of injection hole 101 and running orthogonally with respect to injection hole central axis 200 and line segment are shown with a single-dashed line in FIG. 3.

On that plane vertical to injection hole central axis 200 that is present at the open end of injection hole 101, a recess 203 is provided so as to overhang the open end of injection hole 101. Wall surfaces 204a, 204b, 205a, and 205b parallel to injection hole central axis 200 are formed at the open end of the injection hole by recess 203. The distance between wall surfaces 204a and 205a is set so as to be shorter than the distance between wall surfaces 204b and 205b.

FIG. 4 is a further enlarged view of the injection hole open end shown in FIG. 3, and it is a view of the neighborhood of injection hole, showing the way the fuel is injected from the injection hole. The cross-hatched portion in this view has the shape of a bump relative to recess 203.

The wall surface in the area from point 405 to point 406 and the wall surface in the area from point 407 to point 404 are provided outside the inner wall 201 of the injection hole in the radial direction thereof. This arrangement of wall surfaces enables the open end of the injection hole to be machined accurately and easily since, after the wall

surfaces located in parallel with injection hole central axis 200, downstream with respect to injection hole 101, have been machined, when the injection hole is machined from the upstream end thereof using a punch or the like, members can be applied between the inner wall of the injection hole, the wall surface in the area from point 405 to point 406, and the wall surface in the area from point 407 to point 404.

The fuel injector shown in FIGS. 1 to 4 is an example of a swirl-type fuel injector in which the wall surfaces parallel to injection hole central axis 200, shown in the areas from point 405 to point 406 and from point 407 to point 404, are provided downstream with respect to and outside the injection hole as a means for restraining the radial flow of the fuel.

The fuel injector shown in FIGS. 1 to 4 is a swirl-type fuel injector in which the fuel is rotationally injected from injection hole 101. The pressure near the center of injection hole 101 is reduced by the rotation of the fuel, and the fuel rotates into membrane form and flows downward along injection hole inner wall 201. Accordingly, the fuel is injected from the outer surface of injection hole inner wall 201, with the velocity corresponding to the component in the tangential direction of inner wall 201 (namely, the component in the rotational direction of the fuel) and the

velocity corresponding to the component in the downward direction of injection hole central axis 200. Arrow 403 in FIG. 3 signifies the rotational direction of the fuel, and arrows 408 to 412 denote the direction of fuel injection.

Of all wall surfaces parallel to injection hole central axis 200, only those existing in the areas from point 405 to 406 and from point 407 to point 404 are restraint wall surfaces at which the flow of the fuel in the radial direction of the injection hole is restrained. Since the fuel continues rotating at these restraint wall surfaces, the quantity of fuel injection at the restraint wall surfaces decreases in comparison with the quantity of fuel injection in the area where the flow of the fuel in the radial direction of the injection hole is not restrained. When the walls are tall enough, in particular, almost no fuel is injected from the areas from point 405 to 406 and from point 407 to point 404.

The quantity of fuel injection at the restraint wall surfaces is determined by the ratio between the velocity of the fuel in its rotational direction and the velocity in the direction of the injection hole central axis, and the height of the restraint walls. For example, if the height of the restraint walls is greater than the distance through which the fuel flows in the direction of the

injection hole central axis while rotating in the area from point 405 to point 406, almost no fuel is injected from the area from point 405 to 406.

In the areas from point 404 to point 405 and from point 406 to point 407, however, since the flow of the fuel in the radial direction of the injection hole is not restrained, a large portion of the fuel is injected from these areas.

Since the spread of spraying of the fuel after it has been injected is almost determined by the size of the release areas in which the flow of the fuel in the radial direction of the injection hole is not restrained, the flow rates of the fuels injected from point 404 to point 405 and from point 406 to point 407 can be adjusted by varying the dimensional ratio of these areas.

Here, to ensure that the fuel that has been injected from the release areas mentioned above forms a uniform spraying pattern, it is desirable that the relationship in position between points 406 and 407 that determines the release area in which the flow rate of the fuel injected is greater should be such that the angle in the area from point 406 to point 407 with injection hole central axis 200 as its center is 180 degrees or greater. The reason for this is that when the distances between points 405 and 406 and between points 407 and 404 in the restraint areas

of flow of the fuel in the radial direction of the injection hole are long enough, since the quantities of fuel rotationally flowing out along these wall surfaces will increase and these quantities of fuel will flow out from the starting points of the release areas (namely, points 406 and 404), the density of the fuel flowing out from these points will increase and the density distribution of sprayed fuel will tend to be non-uniform.

When the requirement is satisfied that the relationship in position between points 406 and 407 that determines the release area in which the flow rate of the fuel injected is greater should be such that the angle in the area from point 406 to point 407 with injection hole central axis 200 as its center is 180 degrees or greater, it becomes possible to reduce the circumferential length of the wall surfaces at which the flow of the fuel in the radial direction of the injection hole, to control the quantities of fuel flowing out from the starting points of the release areas (namely, points 404 and 406), and to achieve almost uniform spraying of the fuel injected from the release areas.

As described above, the fuel injected from points 406 and 404 acts to increase the spraying density, and it is known that the reach of the fuel sprayed after being injected becomes long at this section. If the reach of the

fuel sprayed needs to be even longer according to the particular specifications of the engine, the section where these sprays of fuel concentrate can be intentionally created for partially increased reach of the fuel sprayed. In this case, the areas from point 405 to point 406 and from point 407 to point 404, that is to say, the areas where the flow of the fuel in the radial direction of the injection hole is restrained should be extended or the height of the wall surfaces in these areas should be increased.

In the fuel injector shown in FIGS. 1 to 4, the uniformity of fuel spraying can be changed according to the particular size of the areas in which the flow of the fuel in the radial direction of the injection hole is released. When it is desirable that the fuel be particularly uniform, however, it is possible to split fuel spraying into approximately two directions by adopting such structure as shown in FIG. 5, and make the quantities of split fuel spraying different from each other while at the same time making each split spraying pattern uniform.

FIG. 5 shows an example in which wall surfaces 501 and 502 almost parallel to the central axis 200 of the injection hole are provided downstream with respect to and outside this injection hole as fuel flow restraint means, and is a front view of the fuel flow restraint means when seen from the open end of the injection hole. Wall surfaces 501

and 502 are provided at where they come into contact with the fuel after it has been injected following downward flow along injection hole inner wall 201.

The maximum value of such distance Cw between injection hole inner wall 201 and wall surface 501 that brings wall surface 501 and the injected fuel into contact is determined by the ratio between the velocity Vt of the fuel in its rotational direction and the velocity Va of the fuel in the direction of the injection hole central axis, and the height Hw of the restraint walls. In other words, Cw needs to be smaller than at least Hw × Vt/Va. The value of Vt/Va, which is the ratio between the velocity Vt of the fuel in its rotational direction and the velocity Va of the fuel in the direction of the injection hole central axis, can also be estimated from the spread angle θ of fuel spraying, and this relationship can be represented as $\tan\theta = Vt/Va$.

Here, the spread angle θ of fuel spraying is the angle θ at which the fuel that has been injected from the injection hole spreads in the direction of departure from the central axis 200 of the injection hole. FIG. 12 is a cross-sectional view in which the way the fuel is injected from the open end of the injection hole in the fuel injector of FIG. 5 is shown in IV-IV' cross-sectional form. In actual operation, it is possible to photograph such cross

section of fuel spraying as shown in FIG. 12, by radiating sheet-like light (such as a laser beam) to the sprayed fuel so as to pass through the central axis 200 of the injection hole, and photographing the fuel spraying pattern, and thus to measure the spread angle θ of fuel spraying.

In the fuel injector of FIG. 5, the fuel that has flown downstream while rotating along injection hole inner wall 201 is injected in the directions of arrows 511 to 516 at the open end of the injection hole. At this time, portions of wall surfaces 501 and 502 functioning as the fuel flow restraint means, interfere with the injected fuel, with the result that the fuel does not splash in its intended direction.

The fuel that has been injected in the direction of arrow 511 in, for example, FIG. 5 splashes without interference between the fuel and wall surface 502, since the distance L between the injection point 511a of arrow 511 and wall surface 502 is sufficiently long. However, the fuel that has been injected in the directions of arrows 512 and 513 interferes with wall surface 502 and does not splash in the intended direction, because the distance between injection points 512a and 513a and wall surface 502 is too short.

Likewise, the fuel in the direction of arrow 515 interferes with wall surface 501 and does not splash in

the intended direction.

In this way, the presence of wall surfaces 501 and 502 as the fuel flow restraint means, causes interference between the fuel and the wall surfaces, resulting in such distribution-of-spraying as shown in FIG. 6.

Also, such shape of the injection hole open end as shown in FIG. 11 can be used to obtain results similar to those of FIG. 5. In FIG. 11, wall surfaces 501' and 502' parallel to the central axis of the injection hole are provided as a means for restraining the flow of the fuel after it has been injected. The restraint areas where the flow of the fuel is restrained, and the release areas where the flow of the fuel is not restrained can be adjusted according to the particular relationship in position between injection hole inner wall 201 and wall surfaces 501' and 502'.

The fuel release areas α and β in FIG. 11 are determined by the distance L from the injection point of the fuel, the height Hw of wall surfaces 501' and 502', the velocity component Vt of the fuel in its rotational direction, and the velocity component Va of the fuel in the direction of the injection hole central axis.

The injection point 1102 on injection hole inner wall 201 shown in FIG. 11 is a point located exactly at the boundaries of the release areas and the restraint areas,

and the fuel that has been injected from the injection points located in the direction of area β from this point does not come to interfere with wall surface 502'. Injection point 1101 is also located at the boundaries of the release areas and the restraint areas, and the fuel that has been injected from the injection points located in the direction of area α from this point does not come to interfere with wall surface 501'.

At these injection points located at the boundaries, the relationship in position between the wall surface and the injection point is determined by the distance L from the injection point of the fuel, the height Hw of wall surfaces 501' and 502', the velocity component Vt of the fuel in its rotational direction, and the velocity component Va of the fuel in the direction of the injection hole central axis, and this relationship can be represented as $L = Hw \times Vt/Va$.

Injection points 1103 and 1104 are also points located at the boundaries of the release areas and the restraint areas. These injection points located at the boundaries become tangent points when a tangent line is drawn from the positions closest to injection hole inner wall 201 among all points on wall surfaces 501a and 502a (in FIG. 11, these positions are shown as points 1107 and 1108), to the injection hole inner wall.

In this way, the four boundaries between the release areas and the restraint areas can be adjusted according to the particular relationship in position between wall surface 501', wall surface 502', and injection hole inner wall 201, and the particular height of wall surfaces 501' and 502'. As a result of this, the respective sizes of the release areas and the restraint areas can be adjusted. For example, increasing the height of wall surfaces 501' and 502' narrows the release areas. Conversely, distancing wall surfaces 501' and 502' from the injection hole inner wall broadens the release areas.

FIG. 6 is a view of the open end of the fuel injector in which portions of the wall surfaces 205b, 205a, 204a, and 204b that are parallel to injection hole central axis 200 in FIG. 2 come into contact with the injection hole inner wall and form a portion thereof. That is to say, in FIG. 6, the length of injection hole inner wall 201' in the direction of the central axis 200 of the injection hole is made different from the length of the injection hole in its circumferential direction. In the areas from point 601 to point 602 and from point 603 to point 604, the injection hole inner wall is longer as it goes in the direction of injection hole central axis 200 (that is to say, the longitudinal direction with respect to the paper surface of FIG. 6), and functions as a means for restraining

the flow of the fuel in its radial direction. In the areas from point 601 to point 603 and from point 602 to point 604, the injection hole inner wall is shorter as it goes in the direction of injection hole central axis 200, and forms a release area in which the flow of the fuel in its radial direction is not restrained.

Here, the area from point 601 to point 603 as the release area, and the area from point 602 to point 604 differ in spread. More specifically, a plurality of areas at which the length of injection hole inner wall 201' in the direction of injection hole central axis 200 is short are provided in the circumferential direction of the injection hole to ensure that circumferential areas shorter in the length of injection hole inner wall 201' in the direction of injection hole central axis 200 differ from each other in spread.

The use of a fuel injector of such configuration as shown in FIG. 6 produces results similar to those obtained from the use of a fuel injector having such shape of the injection hole open end as shown in FIG. 3. Under such a configuration, such shape of the injection hole open end as shown in FIG. 6 can be easily obtained by conducting cutting operations, near-net-shave plastic working operations, and/or the like, on a general fuel injector whose injection hole open end is not provided with any wall

surfaces parallel to injection hole central axis 200.

FIG. 7 is an epitomic view of the spraying pattern formed by the fuel which was injected by the fuel injector of FIGS. 1 to 6. This figure is a view of the spraying pattern when it is seen downstream with respect to the fuel injector, and this spraying pattern exhibits the cross section within a plane vertical to the central axis of the injection hole.

All fuel injectors shown in FIGS. 1 to 6 have a fuel flow restraint means, which restrains the flow of the fuel in at least two places, and since the sizes of the fuel flow restraint areas differ at each place, the distribution shape of spraying at a cross section vertical to injection hole central axis 200 is split into approximately two directions (701 and 702) as shown in FIG. 7, and at the same time, the respective quantities-of-distribution and spreads of spraying take different shapes.

The distribution shape of spraying can be changed according to the particular spread of the release areas in which the flow of the fuel is not restrained.

More specifically, in the fuel injector of FIG. 4, the distribution shape of spraying can be changed by varying the height Hw (shown in FIG. 2) of the wall surfaces parallel to injection hole central axis 200, and the respective widths (Wa and Wb in FIG. 4). For example, if height Hw

of the wall surfaces is increased, the spread of spraying will be narrower since the effectiveness of the wall surfaces at which the flow of the fuel in its radial direction is to be restrained will increase for the fuel that rotationally flows. It is also possible, by varying Wa and Wb, to change the spread of the release areas at which the flow of the fuel in its radial direction is not to be restrained, and hereby to adjust the flow rate distribution of the approximately bi-directionally split sprays of fuel in the respective directions.

FIG. 8 is a cross-sectional view showing the internal situation of an engine cylinder existing when the fuel injector having the injection hole open end shown in FIGS. 1 to 5 was installed at the air intake valve end of an in-cylinder injection engine equipped with two intake valves and two exhaust valves and a fuel was injected into the combustion chamber during an intake stroke. Since the injection is conducted during the intake stroke, intake valve 803 is in an open status during fuel injection. It is advisable that the fuel injector be installed so that of the flow rate concentration portions of spraying during which the flow rate of the fuel concentrates in approximately two directions, only the portion smaller in flow rate flows towards ignition plug 802 and the portion larger in flow rate flows towards piston 804.

By installing the fuel injector in this way and injecting the fuel, since spraying is split into the direction of piston 804 underneath intake valve 803 and the upward direction of intake valve 803, the fuel density distribution of the mixture inside the cylinder during ignition can be prevented from becoming too lean or the fuel density distribution of the mixture at the side of piston 804 can be prevented from becoming too dense. If the fuel density near ignition plug 802 is too low or too high, these can cause a misfire, namely, failure in the firing of the mixture. Spraying in the direction of ignition plug 802 is therefore effective for preventing a misfire and for suppressing reduced engine output and the emission of an unburned fuel.

The effectiveness described above can be obtained only by providing a fuel flow restraint means downstream with respect to the injection hole, and this is not limited to the shapes of the injection hole open ends shown as examples in FIGS. 3, 4, and 5. The above effectiveness can also be obtained in a fuel injector having the shapes of the injection hole open ends shown in, for example, FIGS. 9 and 10. Even for the shapes of the injection hole open ends shown in FIGS. 9 and 10, two areas in which the flow of the fuel in the radial direction of the injection hole is not restrained are provided in the circumferential

direction of the injection hole, downstream with respect to the open end thereof, and these areas are provided so as to differ from one another in size. Because of this configuration, the distribution of spraying at a cross section vertical to the injection hole axis 200 of the injected spray of fuel concentrates in approximately two directions and spraying can be set to a pattern in which one of the two sprays of fuel is larger in flow rate and the other is smaller in flow rate.

The shapes of the injection hole open ends shown in FIGS. 9 and 10 are also effective in that when the fuel injector is mounted in an in-cylinder injection engine, changes in the spraying direction and spraying density of the fuel due to the creation of deposits during the carbonization off the fuel and lubricants are reduced.

FIG. 10 is a further enlarged view of the injection hole open end shown in FIG. 9, and this view also shows above-mentioned deposits 903 and 904 on, of the entire injection hole open end, only the recessed wall surfaces 205b" and 205a" at the upstream side with respect to the flow (rotational) direction of the fuel.

For the shape of the injection hole open end shown in FIG. 9, the angle at the corner 1005 where the above-mentioned recessed wall surface 205a" at the upstream side and wall surface 204b" are connected is acute and the angle

at the corner 906 where wall surface 205b" and wall surface 204a" are connected is approximately perpendicular. Both the wall surface 205a" connected to corner 905 and wall surface 205b" connected to corner 906 are positioned at where they do not interfere with the injected fuel, and deposits easily accumulate on these wall surface surfaces when the engine is operated. In the case of the injection hole open end shown in FIG. 4, wall surfaces 205b and 205a correspond to the wall surfaces 205b" and 205a", respectively, in FIG. 10. In the case of the injection hole open end shown in FIG. 4, if deposits stick to wall surfaces 205b and 205a, since these deposits will accumulate and grow in the approximately perpendicular direction of wall surfaces 205b and 205a, the deposits will easily interfere with the injected fuel. Therefore, by forming the corners between wall surfaces 205b" and 204a" and between wall surfaces 205a" and 204b" into either an approximately perpendicular or acute angle as shown in FIG. 10, the deposits that accumulate on wall surfaces 205b" and 205a" can be prevented from easily interfering with the fuel that splashes, and as a result, changes in spraying pattern due to be growth of the deposits can be suppressed.

The shapes of the injection hole open ends shown in FIGS. 9 and 10 are designed so that even if the shapes of these open ends are formed by plastic working, the desired

spraying pattern can be obtained. For the shapes of the injection hole open ends shown in FIGS. 9 and 10, wall surfaces 204a" and 204b" located downstream with respect to the flow (rotational) direction of the fuel are formed in the approximately tangential direction of the circumference of injection hole inner wall 201, at the position closest to inner wall 201.

Wall surfaces 204a" and 204b" located downstream with respect to the rotational direction of the fuel in FIG. 10 correspond to the wall surfaces 204a and 204b in FIG. 4. As with wall surface 204a, however, wall surface 204a is not formed in the approximately tangential direction of the circumference of injection hole inner wall 201, at the position closest to inner wall 201, and has an angle.

In general, when an injection hole open end is formed by plastic working, since corners are not easy to work, it is easier to provide radial portions having a curvature. However, at wall surfaces, such as wall surface 204a, that affect the spraying pattern because of interference with the fuel that splashes, since the presence of radial portions changes the distance with respect to the fuel injection positions on the outer periphery of injection hole inner wall 201, the degree of interference with the fuel that splashes differs according to the particular dimensions of the radial portions. For this reason,

factors, such as dimensional differences associated with the manufacture of the radial portions, may cause the spraying pattern to vary from fuel injector to fuel injector.

Hence, by forming, as shown in FIG. 10, wall surfaces 204a" and 204b" in the approximately tangential direction of the circumference of injection hole inner wall 201, at the position closest to inner wall 201, it becomes unnecessary to provide corners at the wall surfaces that affect the spraying pattern because of interference with the fuel that splashes, and it also becomes possible to obtain a fuel injector creating the desired spraying pattern, even when the injection hole open end is processed using a processing method, such as plastic working, that facilitates the manufacture of this open end by providing a curvature at each corner.

As set forth above, according to the present invention, a fuel injector that enables the flow rate of a sprayed fuel to be concentrated into approximately two directions by use of a relatively simple method and makes differences between the respective flow rate distributions, can be supplied by processing the injection hole open end of a swirl-type fuel injector equipped with a single injection hole, and then providing in the circumferential area of the open end of the injection hole a plurality of release

areas different in size and in which the fuel can flow radially. The effectiveness described above can be achieved by changing the shape of the injection hole open end, and thus since new parts do not need to be added, a fuel injector appropriate for the particular specifications of the in-cylinder injection engine can be supplied without any significant increases in costs.

According to the fuel injector pertaining to the present invention, an ideal spraying pattern for the intended in-cylinder injection engine can be obtained.